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RESEARCH MEMORANDUM

ROLLING EFFECTIVENESS OF A THIN TAPERED WING HAVING PARTIAL-SPAN AILERONS AS DETERMINED BY ROCKET-POWERED TEST VEHICLES

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

The rolling effectiveness of a thin, tapered, and essentially unswept wing having outboard partial-span plain ailerons has been determined by means of rocket-powered test vehicles. The rolling power decreased abruptly in the Mach number range from 0.85 to 0.95 and more gradually at higher speeds. At the maximum Mach number of the tests (1.95), the rolling effectiveness was only 20 percent of that at a Mach number of 0.85. Good agreement was obtained with the theory of NACA TN 1890 which takes into account wing elasticity.

INTRODUCTION

The rolling effectiveness of a thin, tapered, and essentially unswept wing having outboard partial-span plain ailerons has been determined over the Mach number range from 0.85 to 1.9, by means of rocket-propelled test vehicles using the technique described in reference 1. The variation of total drag coefficient with Mach number was also obtained. In order to obtain an indication of aeroelastic effects, wings of two different stiffnesses were used: one was made of solid steel and the other of solid duralumin. The results of these tests and a comparison of the measured variation of rolling effectiveness with Mach number with that calculated by the theoretical method of reference 2, which takes into account wing elasticity, are presented herein.

SYMBOLS

$\frac{pb}{2V}$	wing-tip helix angle, radians
C_D	total drag coefficient based on exposed wing area (1.563 sq ft)
m_θ	wing-torsional-stiffness parameter, inch-pounds per radian
m	couple applied near wing tip in plane parallel to model center line and normal to chord plane, inch-pounds
θ	local wing-twist angle produced by m measured in plane parallel to that of m, radians
p	ambient static pressure, pounds per square foot
p_o	standard sea-level static pressure (2116 lb per sq ft)
δ	deflection of each aileron, degrees
R	Reynolds number based on mean exposed wing chord of 0.642 foot
M	Mach number
c	wing chord parallel to model center line
$\Lambda_{c/2}$	sweepback angle of 50-percent chord line

TEST VEHICLES AND TESTS

The general arrangement of the test vehicles is shown in figures 1 and 2. The details of the wing-aileron arrangement are shown in figure 3. Two models were flown: in one, the wing panels were made of duralumin and in the other, of steel. The measured spanwise variation of wing torsional stiffness obtained with the two materials is shown in figure 4. The wings had an aspect ratio of 2.91 obtained by extending the leading and trailing edges to the model center line, a taper ratio of 0.4, 8° of sweepback of the 50-percent chord line, and modified hexagonal airfoil sections of 0.045 thickness ratio. The ailerons had unswept hinge lines and chords equal to 25 percent of the local wing chord. The aileron deflection was set at the desired value of 5° during construction and was nonadjustable. The actual measured aileron deflections are listed in figure 5.

The test vehicles were accelerated by a two-stage rocket-propulsion system to a Mach number of about 1.9. During coasting flight, following burnout of the rocket motor, time histories of the rolling velocity produced by the ailerons (obtained with spinsonde equipment, reference 3) and the flight-path velocity (obtained with Doppler radar) were recorded. These data, in conjunction with atmospheric measurements obtained with radiosondes, permitted the evaluation of the rolling effectiveness parameter $\frac{pb/2V}{\delta}$ as a function of Mach number. The variation of the drag coefficient of the test vehicles with Mach number was obtained by differentiation of the flight-path-velocity time history. The scale of the tests is indicated by the curve of Reynolds number against Mach number shown in figure 5. A more complete description of the method is given in reference 1.

ACCURACY

The error in the determination of the quantity $\frac{pb/2V}{\delta}$ for any one model is estimated to be within ±0.0004 and ±0.0002 at the lowest and highest test Mach numbers, respectively. However, experience has shown that the $\frac{pb/2V}{\delta}$ obtained from nominally identical models may vary, because of small physical differences in the models, by as much as ±0.0005 and ±0.0003 at the lowest and highest test Mach numbers, respectively.

The errors in the drag coefficient and the Mach number are estimated to be within ±0.005 and ±0.002 at the lowest and highest test Mach numbers, respectively.

The values of $\frac{pb/2V}{\delta}$ obtained during flight deviated slightly from steady-state values because the models experienced a continuous rolling acceleration or deceleration. The deviation reached a maximum of about 10 percent in the Mach number range from 0.93 to 0.97. The deviation was negligible over the remainder of the Mach number range investigated. The results have not been corrected for this effect.

RESULTS AND DISCUSSION

The results of the investigation are given in figure 5 as curves of the rolling effectiveness parameter $\frac{pb/2V}{\delta}$ and total drag coefficient C_D as functions of Mach number. It should be noted that the quantity $\frac{pb/2V}{\delta}$

is simply the ratio of $pb/2V$ to δ for the particular aileron deflections tested. The variation of the pressure ratio p/p_o with Mach number obtained during the test flights has also been included to permit the correction of the measured values of rolling effectiveness for the effects of wing twisting.

As shown in figure 5, the rolling effectiveness was reduced abruptly in the Mach number range from 0.85 to about 0.95. The rolling effectiveness at the highest supersonic Mach numbers was only about 20 percent of that at $M = 0.85$. The rolling effectiveness of the steel-wing configuration was only slightly higher than that of the duralumin configuration indicating that the results for both configurations approach those which would be obtained with infinitely rigid wings.

In figure 6, the measured values of rolling effectiveness are compared with those obtained from reference 2. In making the calculations, it was necessary to make the reasonable assumption that the wing was unswept at the 50-percent chord line. The theory satisfactorily predicts the rolling effectiveness of the configurations tested.

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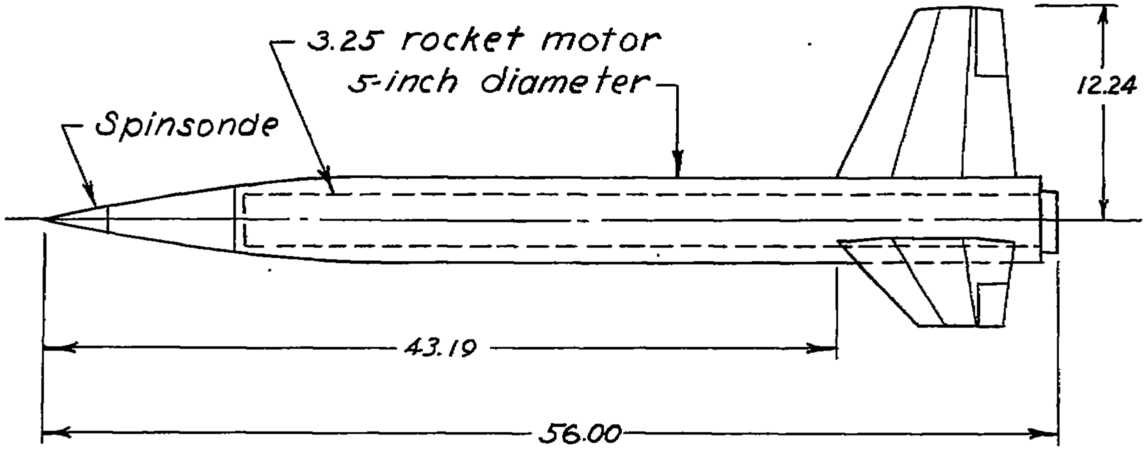
REFERENCES

1. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM L7D02, 1947.

2. Tucker, Warren A., and Nelson, Robert L.: The Effect of Torsional Flexibility on the Rolling Characteristics at Supersonic Speeds of Tapered Unswept Wings. NACA TN 1890, 1949.

3. Harris, Orville R.: Determination of the Rate of Roll of Pilotless Aircraft Research Models by Means of Polarized Radio Waves. NACA TN 2023, 1950.



Fuselage Station	Ordinates Diameter
0	0
2.50	1.22
5.00	2.30
7.50	3.16
10.00	3.92
12.50	4.52
15.00	4.88
17.50	5.00

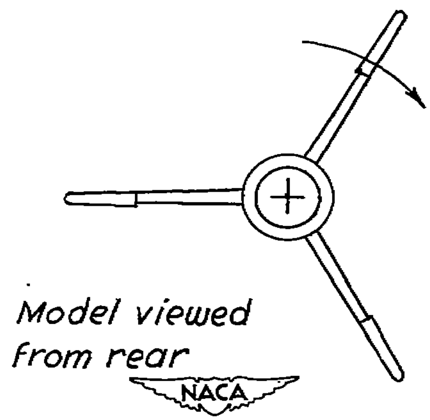


Figure 1.- General arrangement of test vehicles. All dimensions are in inches.

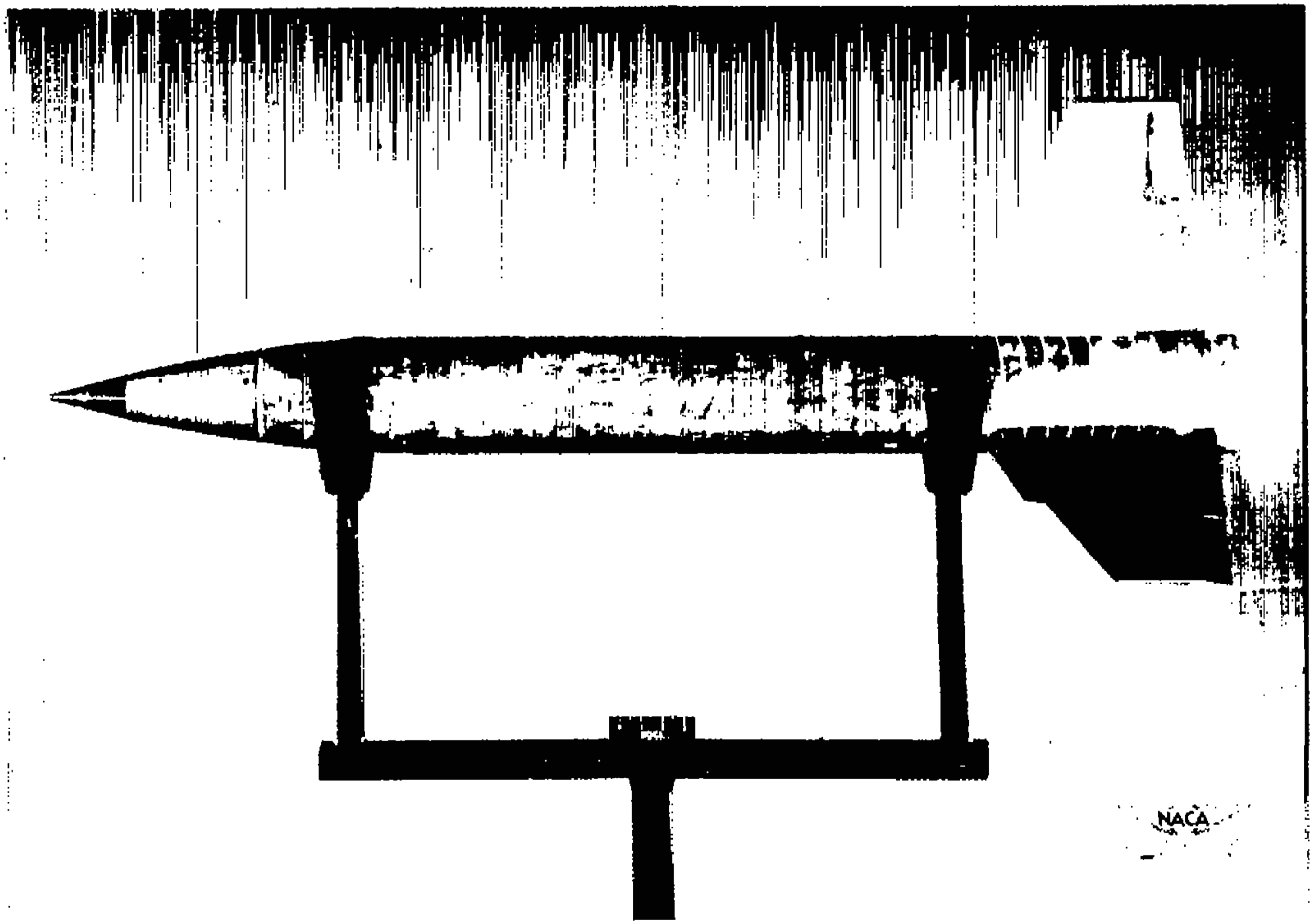


Figure 2.- Typical test vehicle.

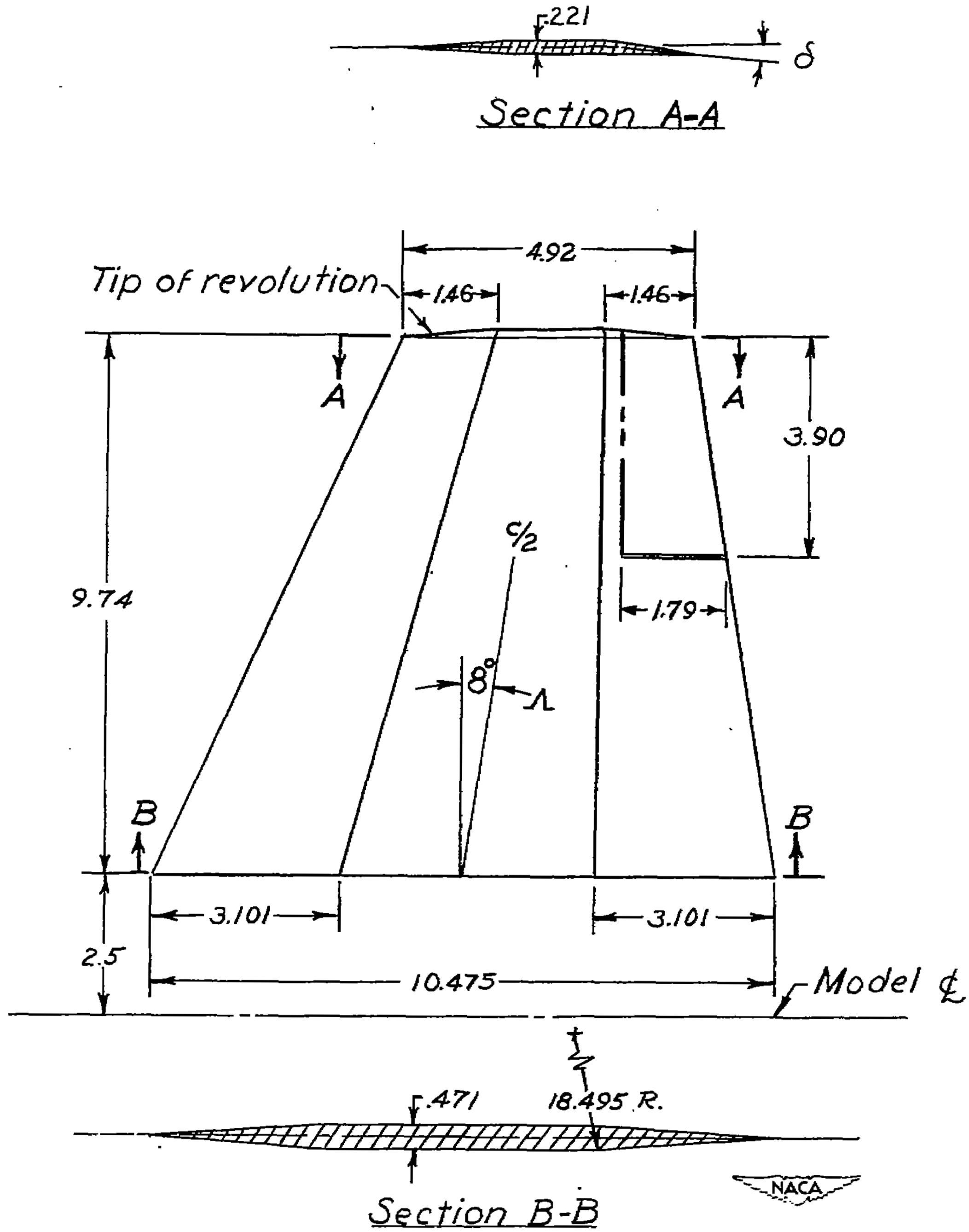


Figure 3.- Wing plan-form details. All dimensions are in inches.

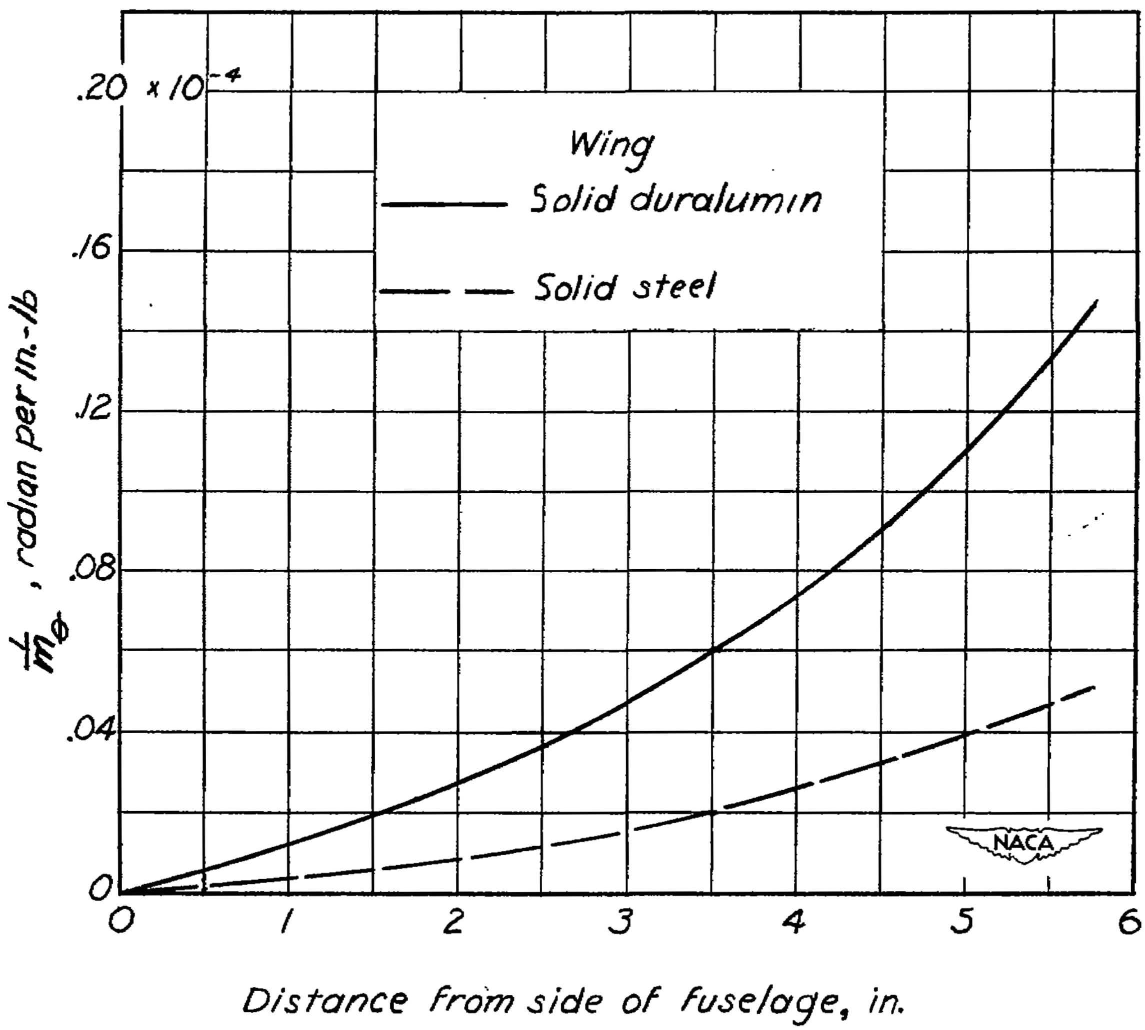


Figure 4.- Measured spanwise variation of reciprocal of wing torsional stiffness parameter.

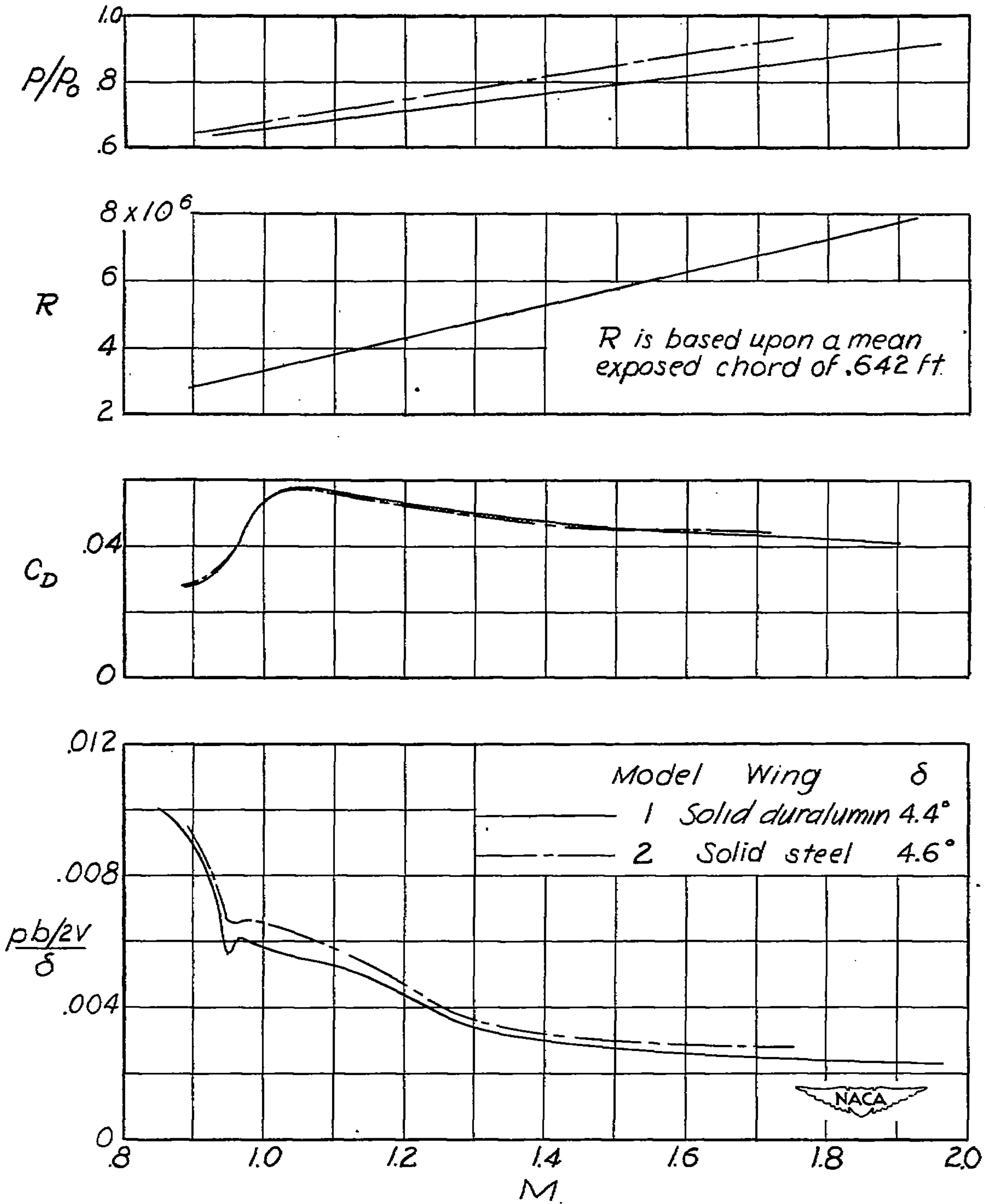
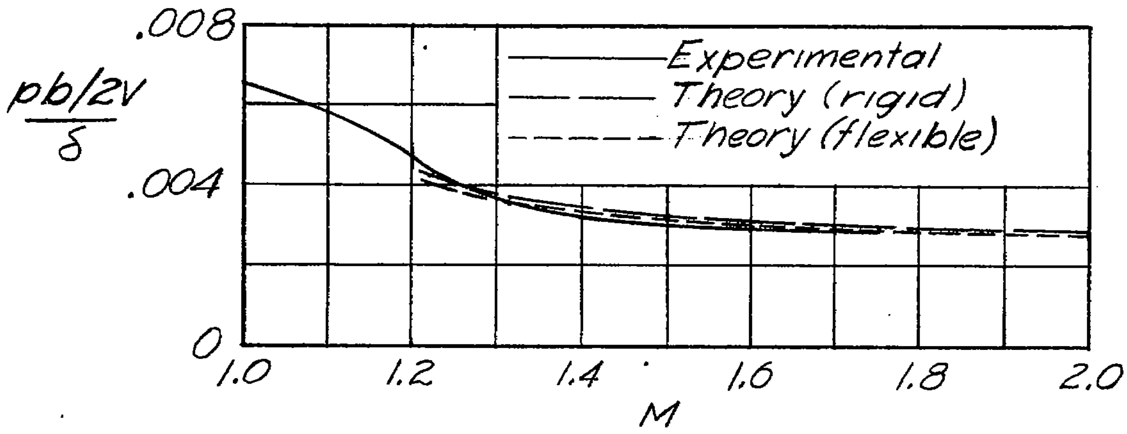
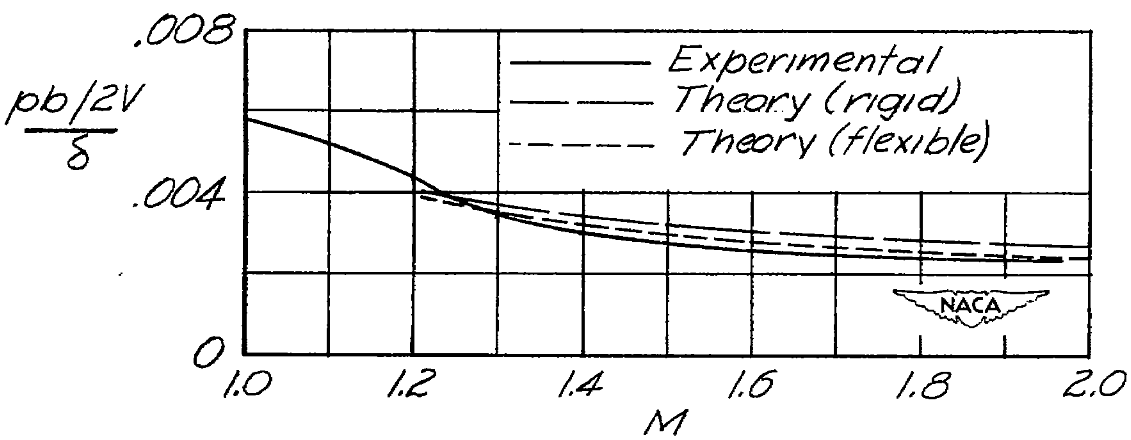


Figure 5.- Test results.



(a) Steel wings.



(b) Duralumin wings.

Figure 6.- Comparison of experimental and theoretical results from reference 2.